Naval Research Laboratory

Washington, DC 20375-5000 NRL Memorandum Report 6559 Date: 15 November 1989

A TEST METHOD FOR MEASURING CORONA INCEPTION VOLTAGE FOR TRANSDUCER AUTOTRANSFORMERS

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REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*	2. REPORT DATE 15 November 1989	3. REPORT TYPE AND DATES COVERED FINAL - FY87/FY88

4. TITLE AND SUBTITLE
A TEST METHOD FOR MEASURING CORONA INCEPTION VOLTAGE FOR TRANSDUCER AUTOTRANSFORMERS

5. FUNDING NUMBERS
WU - 59-0584

6. AUTHOR(S)
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7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
NAVAL RESEARCH LABORATORY
UNDERWATER SOUND REFERENCE DETACHMENT
P.O. BOX 568337
ORLANDO, FL 32856-8337

8. PERFORMING ORGANIZATION REPORT NUMBER
NRL MEMORANDUM
REPORT 6559

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
NAVAL SEA SYSTEMS COMMAND
WASHINGTON, DC 20362-5101

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited.

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

An autotransformer corona inception test circuit has been developed and a prototype has been constructed and demonstrated. Circuit diagrams and component values are presented. Ancillary equipment for the test is identified and recommended, test procedures and precautions are presented, and measured corona inception voltage data as well as pictorial data are presented for autotransformers of different manufacture and type. Included is a computer program which is used to model and calculate values of test circuit filter components. Keywords

14. SUBJECT TERMS
Corona — Transformers
Autotransformer — Transducer reliability (electroacoustic), (jhd)

15. NUMBER OF PAGES
38

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	UL

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INTRODUCTION

A small but significant percentage of failures in high-power fleet sonar transducers are due to breakdown of electrical insulating or dielectric materials. A physical phenomenon that contributes to these failures is corona which is a discharge of electricity caused by ionization of the surrounding medium when the voltage gradient exceeds a certain critical value. The frequency of discharge is above 75 kHz. At high operating voltages corona occurs before dielectric breakdown, but will, in time, deteriorate insulating materials and cause dielectric failure.

One of the components in a typical high-power transducer that is susceptible to corona is the autotransformer (tapped power inductor) which is used to augment tuning, transmit voltage response, and transmit impedance. These transformers usually operate at secondary voltages in the range of 1500 V, but may be as high as 5000 to 6000 V in some instances. A suitable corona test is valuable in determining if a particular transformer design or production transformer has corona at relatively low voltages. Such a situation may be indicative of poor terminal design, voids or air pockets in the coil coatings or potting compounds, and an indication of premature failure in the normal operating environment.

This report covers the development of a corona inception voltage (CIV) test that can be applied as a qualification, quality control, or quality assurance provision in a transducer autotransformer specification.

BACKGROUND

In 1987, General Electric (GE) and Raytheon were awarded production contracts to fabricate TR-317( ) sonar transducers according to a government developed Fabrication Specification Package (FSP). The FSP contains requirements that are deemed necessary for the composite transducer to achieve a 15-year service life. One such requirement was a corona specification for the autotransformer. As a part of the FSP development. certain critical assemblies of the transducer, which included the transformer, were procured by sample buys (in small quantities) to proof the FSP drawings. Because of limited financial resources in the years prior to the TR-317( ) production contract award, some of the sample buys were still in progress at the time of contract award.

During the transformer sample buy, a transformer contractor (Harder, Inc.) expressed concern about the validity of the corona requirements and the test method specified in the transformer drawings [1]. The concerns were: (1) the validity of a quantitative limit and measure of corona; and (2) the effectiveness of the specified filter circuit in attenuating the fundamental frequencies and passing the frequencies associated with corona. After consultation with the Naval Sea Systems Command (NAVSEA) it was determined that Harder's concerns were valid. These concerns led the TR-317( ) production contractors, with NAVSEA concurrence, to submit a Deviation/Waiver requesting modifications to the transformer drawing with respect to corona measurement, corona suppression, and abatement. In order to prevent delays in receiving First-Article transducers, the waiver (applicable to these transducers only) was allowed.

Since the waiver was allowed for First-Article transducers only, and at the beginning of production NAVSEA would again have to address the problem, NRL-USRD accepted the task of developing a technically defensible corona test for the TR-317 transformer that could be applied to the production transformers.

Several references are made in this report, to the TR-330A transducer (NAVSEA Drawing 53711-5517085), and TR-330A transformer corona data are presented. Corona requirements were not included in the original TR-330A FSP because the corona specifications for the TR-317( ) transformer were indefensible, and there were problems associated with corona testing the TR-317( ) transformer. The TR-317( ) FSP was used as a template for the TR-330A, thus the solution for the problem in the TR-317( ) also becomes the basis for a validated corona test for the TR-330A transformer.

APPROACH AND OBJECTIVES

The approach to the problem was to use the corona test circuit and specification in the TR-317( ) transformer drawing and make the necessary changes to provide a technically defensible test. That is, "defensible" in the sense that if a transformer failed to pass the test, the transformer would be questionable -- not the measurement, methodology, or test circuit.

The first step in the approach was to eliminate the *quantitative* test procedure and replace it with a *qualitative* test procedure. Therefore, instead of specifying a *quantitative* measure of corona current at some test voltage, the approach would be based on the *qualitative* detection of corona inception. That is, the goal was simply to be able to detect when corona first occurs, and measure the voltage at which it occurs.

The hardware for the test must be specified and tested to determine if corona can be detected reliably, repeatedly, and economically at the transformer assembly level.

The items needed to accomplish a CIV test, not including ancillary equipment, are:

- A circuit to resonate with the autotransformer at the approximate center of the operating frequency range.
- A high pass filter to attenuate the lower fundamental frequencies, yet allow the higher corona frequencies to be passed for detection.
- A properly constructed Faraday shield to provide protection from outside electromagnetic interference which can mask the corona signal.

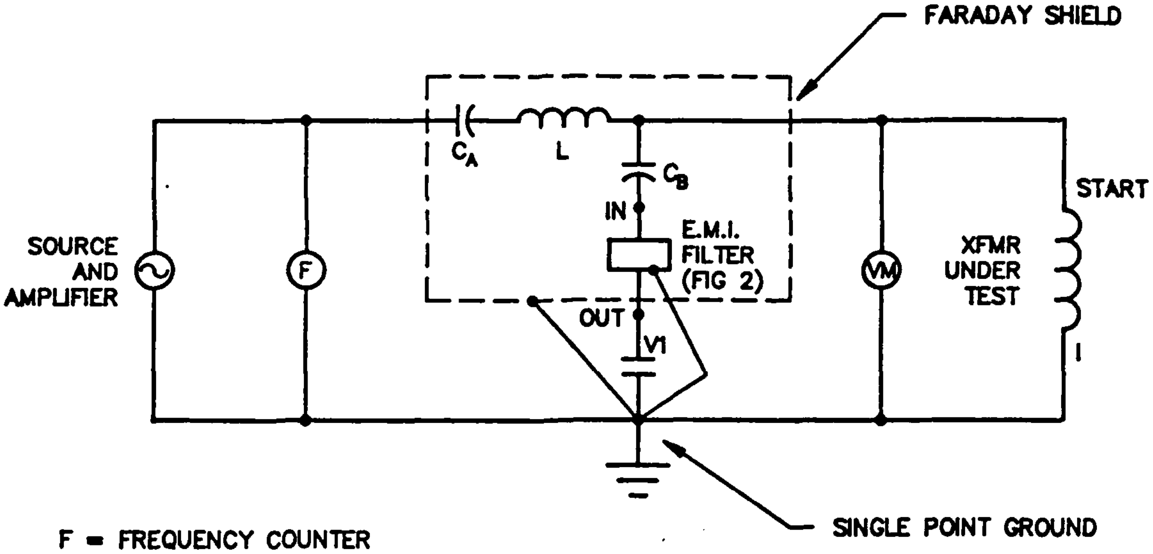
CIV TEST CIRCUIT DESCRIPTION

The corona test circuit and test procedure originally developed by the TR-317R transducer design team was inadequate for its intended purpose. Figure 1 depicts an improved CIV test circuit, including the ancillary test equipment, that has been developed from the original test circuit and validated. In Fig. 1, capacitor C_A, inductor L, and capacitor C_B are the essential parts of the autotransformer resonant circuit: C_A resonates with the transformer under test, C_B isolates the EMI filter from the rest of the circuit to prevent loading, and L enhances the corona detection by preventing the source from shunting the corona signal. C_A is calculated from the formula for the resonance frequency of an ideal parallel LC circuit which is,

$$f_r = \frac{1}{2\pi\sqrt{L_T C_A}} \tag{1}$$

If, in Eq. (1), we define L_T as the inductance of the transformer under test, and f_r as the approximate center of the transformers operating frequency band, then

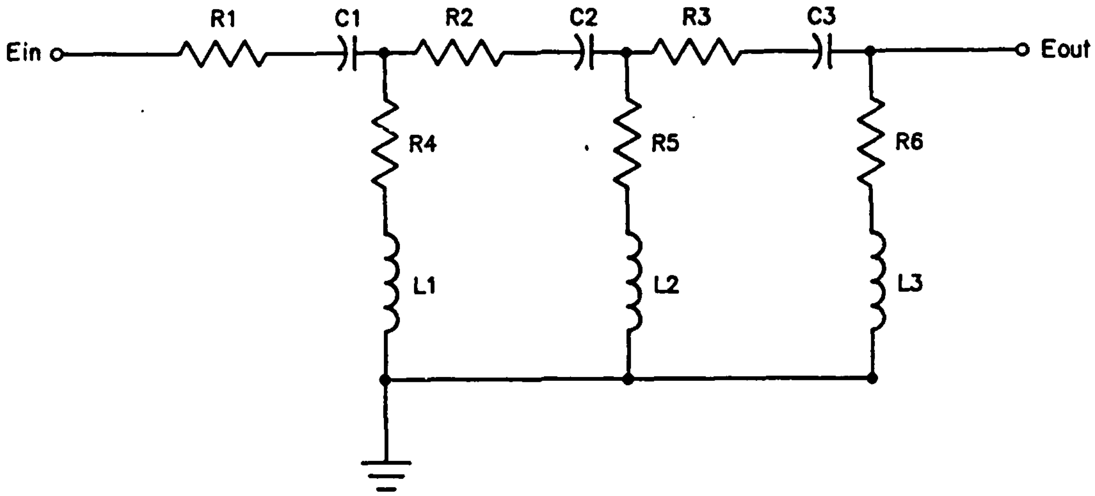
$$C_A = \frac{1}{4\pi^2 f_r^2 L_T} \tag{2}$$



F = FREQUENCY COUNTER
C = 5000pF 5000 WVDC .1%DF
C = 150 pF CAPACITOR 5000 WVDC .1%DF
V1 = INPUT TO OSCILLOSCOPE
VM = VOLTMETER, FLUKE 8922A TRUE RMS OR EQUIVALENT (USE 100X OR 1000X PROBE).
L = 2.4mH INDUCTOR PIE WOUND LOW CAPACITANCE
SOURCE AND AMPLIFIER = WAVETEK 182A FUNCTION GENERATOR AND INSTRUMENTS INC., LDV2-6, 10KVA POWER AMPLIFIER OR EQUIVALENT.

Fig. 1 - CIV test circuit.

Figure 2 is a schematic diagram of the EMI filter section of the circuit shown in Fig. 1 and depicts the three stage ladder, R-C, R-L, high-pass filter which passes the corona signal to an appropriate detector. The circuit component values shown in Fig. 2 were determined by using equations derived from the model of a three-stage, high pass, L section filter. The circuit values were verified on a computer program, developed by the Naval Ocean Systems Center (NOSC) for an L section filter. The computer program for the circuit is contained in the appendix.



R1, R2, R3 = 4000 OHMS, 5W
R4 = 400 OHMS 5W
R5 = 300 OHMS 5W
R6 = 200 OHMS 5W

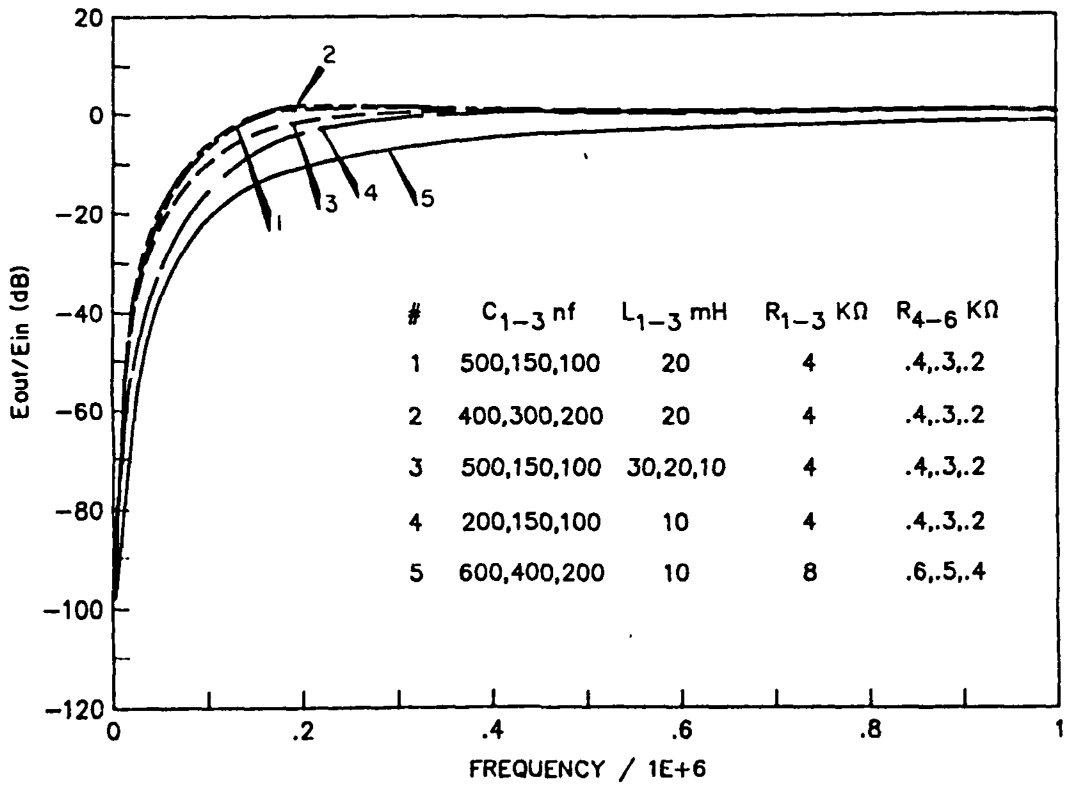
C1 = 0.5uF 3KVDC
C2 = 0.2uF 3KVDC
C3 = 0.1uF 3KVDC

L1, L2, L3 = 0.02H 0.1AMP

COMPONENTS TOLERANCE = ±5%

Fig. 2 - EMI filter for CIV test circuit.

Several different circuits were evaluated to determine the five most optimum values shown in Fig. 3, although all the circuits evaluated were, to some degree, acceptable in that the fundamental frequency would be attenuated while allowing the corona frequency to be passed through for detection. Circuit value set #1 was chosen because at no time did E_{out}/E_{in} exceed 0 dB, and set #1 exhibited a steep cutoff slope. Set #2 also exhibited a steep cutoff slope, but exceeded 0 dB E_{out}/E_{in}. The other circuit values would allow attenuation of the fundamental frequency, but not to the same degree as set #1. The calculated values (along with actual tests) verified that the circuit would be acceptable for testing both TR-317( ) and TR-330 transformers with only a change in the value of capacitor C_A shown in Fig. 1.



#	C_{1-3} nf	L_{1-3} mH	R_{1-3} KΩ	R_{4-6} KΩ
1	500,150,100	20	4	.4,.3,.2
2	400,300,200	20	4	.4,.3,.2
3	500,150,100	30,20,10	4	.4,.3,.2
4	200,150,100	10	4	.4,.3,.2
5	600,400,200	10	8	.6,.5,.4

Fig. 3 - EMI filter characteristics versus frequency.

The quality of the components used in the circuit is very important to eliminate the possibility of corona in any other part of the circuit except the transformer under test. All capacitors are oil-filled polypropylene capacitors and have a dielectric dissipation factor of 0.001 (0.1%) or less.

The inductors for the CIV test circuit were designed and fabricated at NRL-USRD. Inductor L, in Fig. 1, consists of 18 turns of #25 polythermaleze insulated copper wire, pi wound on a three section bobbin. The bobbin assembly is placed into a Ferroxcube #2616 P 3C8 ferrite cup core, and the Q, measured on a RLC bridge, is 68. Inductors L1, L2, and L3 in Fig. 2 consist of 223 turns of #25 polythermaleze insulated copper wire in a Ferroxcube #3622 PA400 3B7 ferrite cup core; and the measured Q is approximately 270.

Figures 4a through 4f are photographs of the test circuit chassis and enclosure. Excluding the ancillary equipment, only the transformer under test is not within the shielded enclosure.

The Faraday shield for the circuit consists of the aluminum chassis bottom, the chassis faceplate, and the copper wire mesh attached by screws to the chassis as shown in Fig. 4c. Shielding the circuit could also be accomplished by enclosure in a metal box or cabinet instead of using a copper mesh. The mesh was used during the development phase to visually determine the existence of any arcing. The circuit components and wiring should be isolated from the the enclosure to minimize any interaction between the return current path of the circuit and the grounded case shield which should not have any current flow. This condition is implied by the single point ground connection shown in Fig. 1.

The electrical connections between circuit components on the chassis are made with 15 kV dc rated, silicone insulated, 20 AWG stranded copper wire.

Fig. 4a - Front view of faceplate.

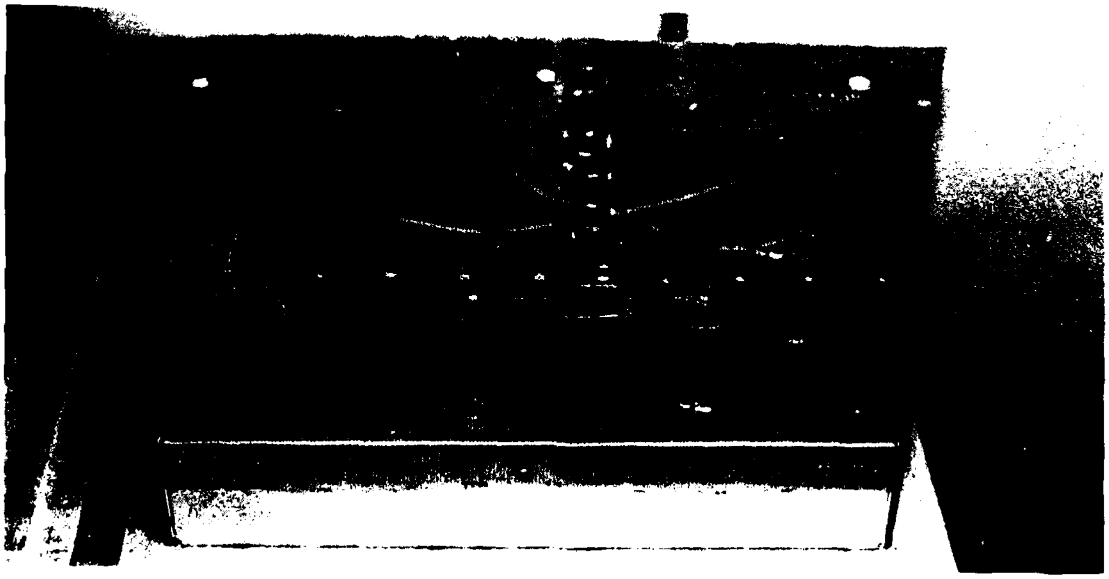


Fig. 4b - Rear view shield mesh installed.

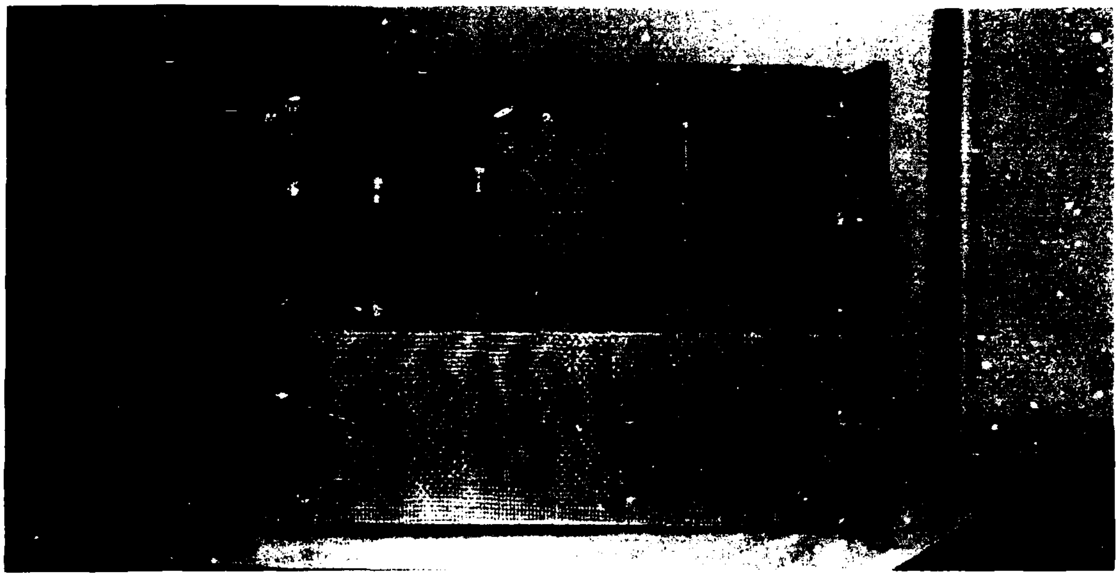


Fig. 4c - Side view Faraday shield/chassis.

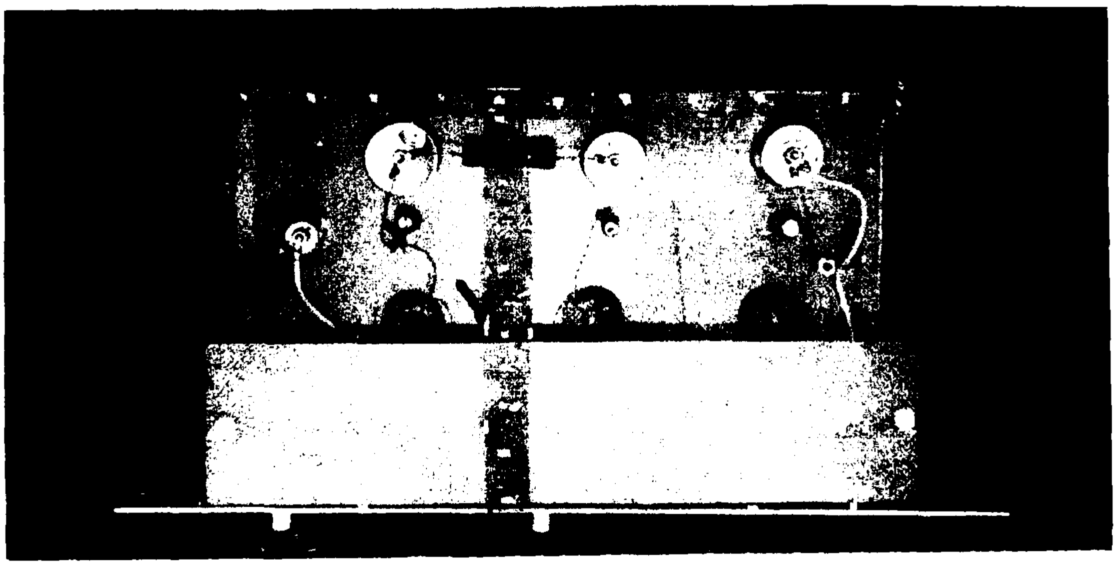


Fig. 4d - Top view mesh installed.

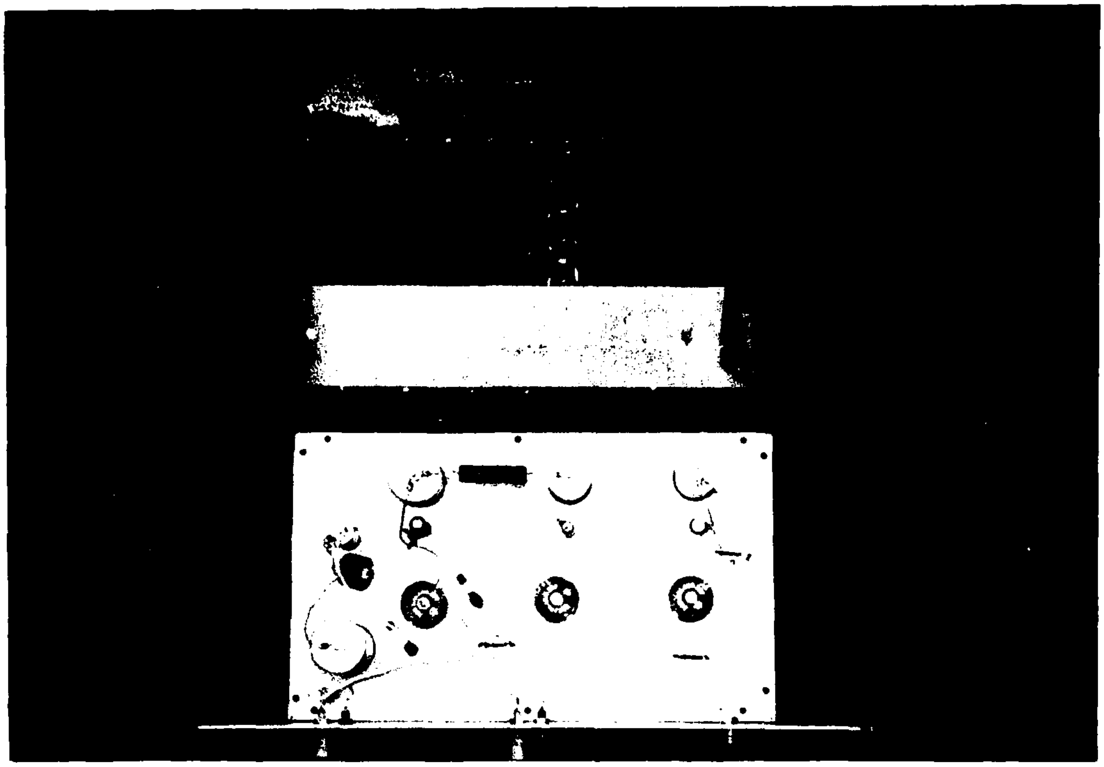


Fig. 4e - Top view internal components/mesh shield.

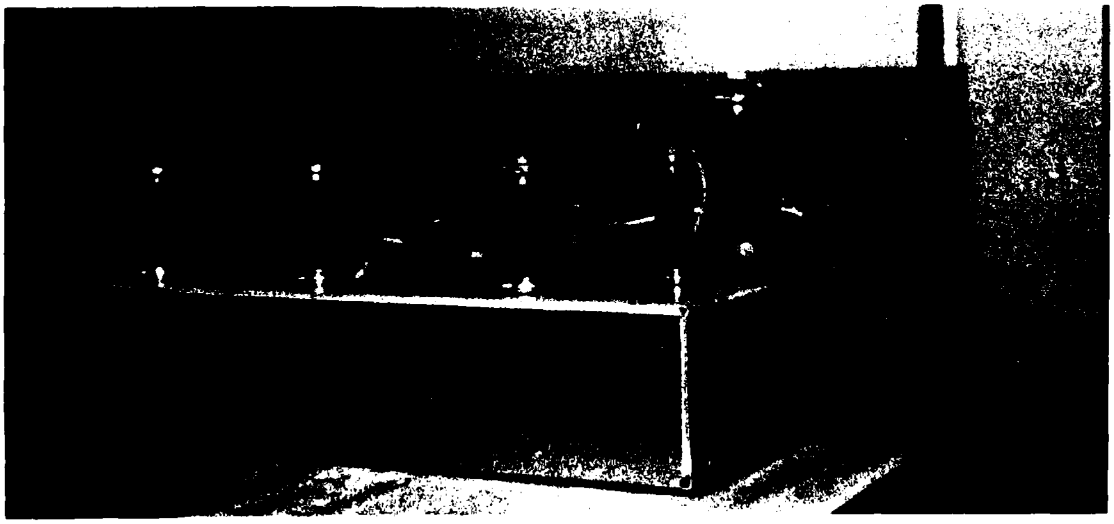


Fig. 4f - Rear view component mounting.

CIV TEST PROCEDURES

An oscilloscope with a measurement capability of dc to at least 20 MHz should be used. The output connector V1 is connected to the vertical input of the oscilloscope. The oscilloscope should be preset to a vertical input sensitivity of 2 V/division and a horizontal sweep time of 20 μs/division. The rest of the setup is done as shown in Fig. 1.

The hookup wire from the power amplifier output should be a single twisted pair. All other circuit connections are made with RG-58/U coaxial cable (which will withstand 2 kV) to further shield the circuit from EMI.

In evaluating test procedures, measurements were made with and without transformer shielding and the results indicated that a shield was not necessary for the transformers tested (TR-317 and TR-330A autotransformers). In extremely noisy environments, transformer shielding can easily be accomplished, if necessary, but all shielded ground connections to the circuit should be made at a single point on the chassis.

To make the CIV test:

1. Adjust the input voltage as read on the VM to the transformer to approximately 5 to 10V at the approximate resonant frequency [fr, Eq.(1)] of the autotransformer under test. Then carefully adjust the frequency generator to the frequency that produces the maximum voltage on the voltmeter, or the maximum amplitude waveform on the oscilloscope.

2. After the frequency is adjusted to resonance, carefully increase the applied voltage as read on the VM until the corona inception "hash" is sporadically observed on the oscilloscope. Corona inception is evidenced by the sporadic high-frequency "hash" type oscillations on the oscilloscope waveform and by an increase in the voltmeter reading. Record the frequency and the voltage at which corona inception is observed.

3. Repeat the first two steps two more times to insure repeatability.

Figures 5 and 6 serve to illustrate how the corona "hash" appears on the oscilloscope waveform. Figure 5a shows the scope wave form for a TR-330A transformer under normal drive conditions and Fig. 5b under higher drive conditions that has produced corona. Note that a small amount of the drive frequency is evident in the oscilloscope display; but, as seen in the high-drive condition, Fig. 5b, is not detrimental to the observance of the corona "hash" in Fig. 5b. Figures 6a and 6b show the same drive conditions just described, respectively, for a TR-317 transformer; Fig. 6a shows a clean waveform; and Fig. 6b shows a waveform with high-frequency corona "hash." If desired, corona detection can be augmented if an AM radio receiver is available, placed near the transformer under test, and tuned to 550-560 kHz; sporadic noise (loud static) will be heard from the receiver at the same time that corona "hash" (as illustrated in Figs. 5b and 6b) appears on the oscilloscope waveform.

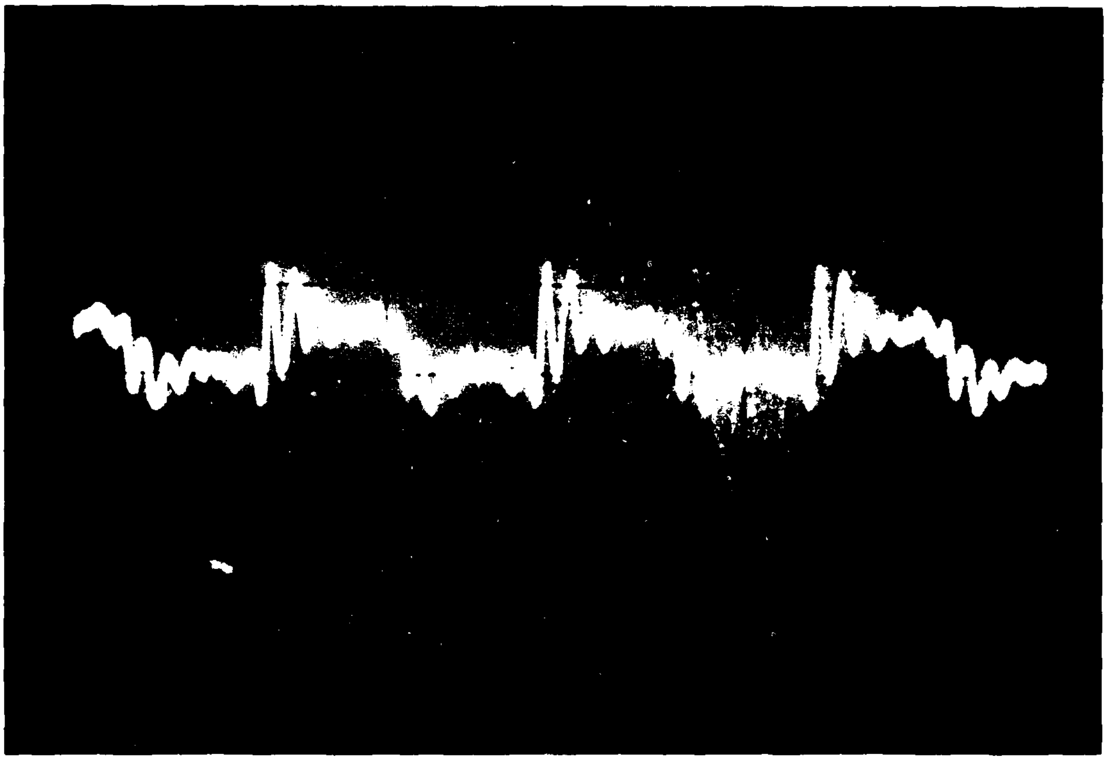


Fig. 5a - Output of the CIV test circuit for a TR-330A autotransformer under normal drive conditions.

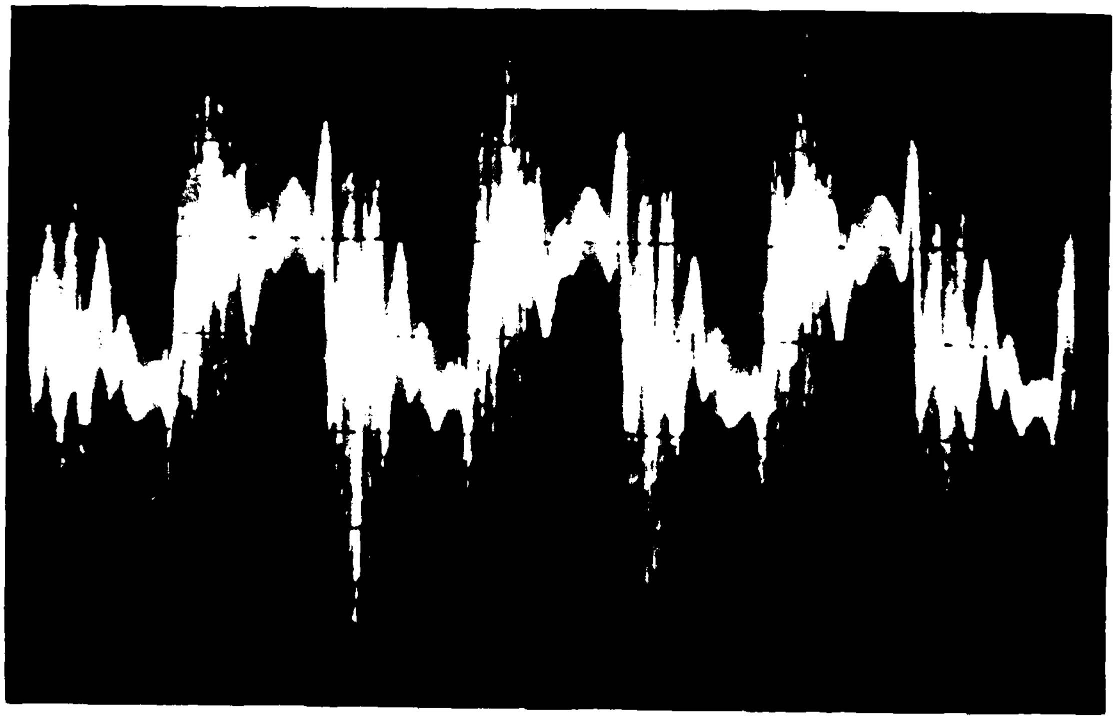


Fig. 5b - Output of the CIV test circuit for a TR-330A autotransformer under high-drive conditions with corona "hash."

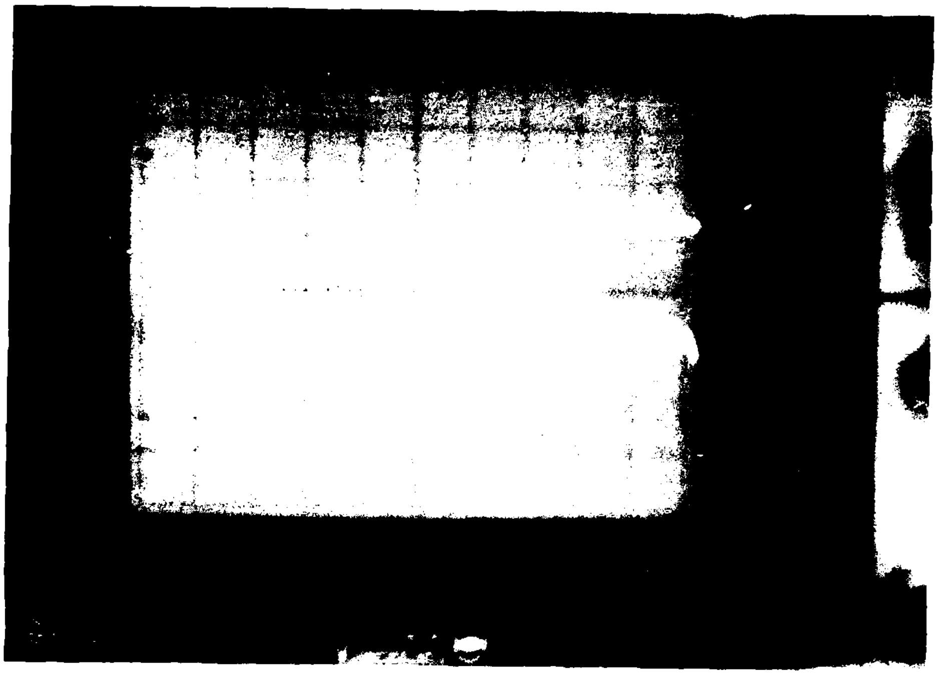


Fig. 6a - Output of the output of the CIV test circuit for a TR-317 autotransformer under normal drive conditions.

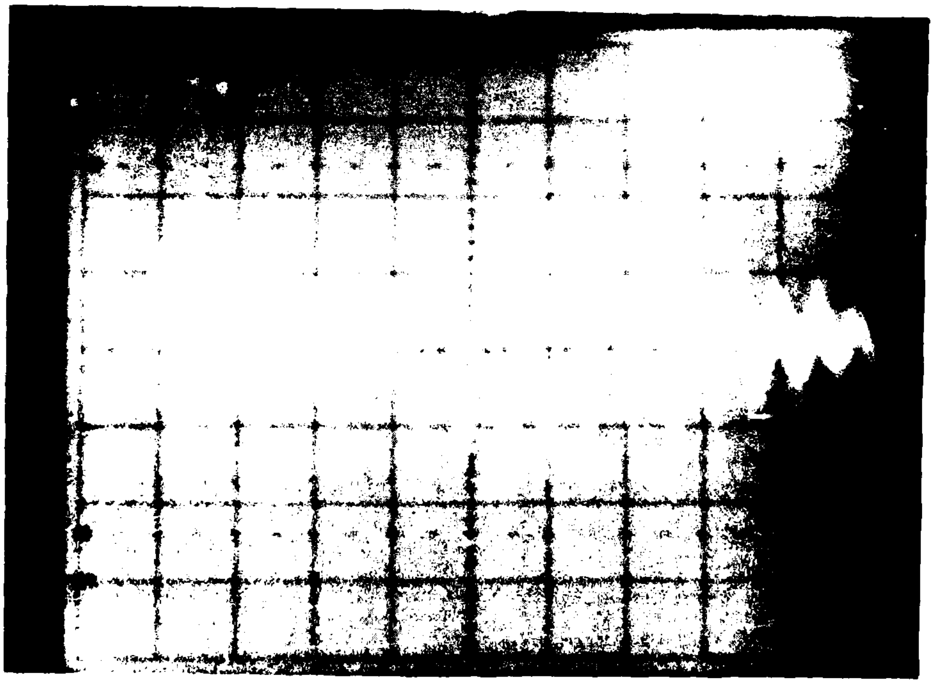


Fig. 6b - Output of the CIV test circuit for a TR-317 autotransformer under high-drive conditions with corona "hash."

CIV TEST PRECAUTIONS

The amplifier chosen for the CIV test must be adequate for the intended purpose. For the TR-317 transformer test circuit, shown in Fig. 1, the power amplifier should be an Instruments Inc. Model LDV 2-6, 10 kVA or an equivalent that will supply the current and voltages necessary for the test. For the TR-330A transformer, a McIntosh Model MC-2500, 1 kVA amplifier or equivalent is adequate. Since a high impedance output may make the test circuit susceptible to high-frequency noise pickup, one should use the minimum impedance setting on the amplifier compatible with providing the required test voltage across the transformer.

For the TR-317 corona test circuit, capacitor C_A should be the value shown in Fig. 1. For the TR-330A transformer corona test, the value of C_A should be 3000 pF.

It should be emphasized that corona occurs in the presence of high voltages; therefore, high voltage is required to make the test. The measurements should be made with care and respect for the operating conditions to prevent serious electrical shock to the operator.

CIV TEST DATA

The CIV test circuit and procedures previously described have been used to determine the CIV for several TR-317 and TR-330A production transformers and for experimental TR-330A toroidal autotransformers. The TR-317 group contains transformers salvaged from TR-317 autopsies, transformers from the TR-317R sample buy, and GE TR-317( ) production transformers -- the latter two made by Harder, Inc. and Chloride, respectively. The transformers are fabricated in a variety of ways; i.e., varnish coated but not potted, potted, etc., these conditions are noted with the measured data in Tables 1 and 2.

The TR-330A group contains transformers which are potted except for two experimental toroidal transformers which are unpotted. The unpotted transformers were included in the test to demonstrate the difference in CIV between unpotted and potted transformers.

Table 1 provides data from the CIV tests on the TR-317 transformers. The serial numbers shown in the table are the actual serial numbers shown on the transformers, except for those that have an A prefix (the A prefix indicates the serial number of the transducer from which the transformer was removed). The table indicates, in the column headed "Type," certain conditions and materials used in the fabrications of the transformer. Table 1a is corona test data for TR-317 transformers, some of which were salvaged from autopsies. Table 1b is test data for 6 GE TR-317( ) production transformers (Chloride). Tahle 1c shows the test data from 6 TR-317R Sample Buy (Harder) transformers. The frequency data shown in Table 1 is relative to the electrical resonance of the transducer in-water (peak of free-field voltage sensitivity). The table indicates three independent measurements on each transformer. Measurements were taken at approximately 1 minute intervals.

Table 1a - Corona Test Data for TR-317 Autotransformers.

		Relative Freq		Relative Freq		Relative Freq		CIV	
Ser #	CIV	(Hz)	CIV	(Hz)	CIV	(Hz)	Type	Mean	Std Dev
013	2731	790	2522	858	2561	852	Coated	2604	111
405	2915	586	2665	583	2596	597	Coated	2725	168
H-1	3115	462	2557	499	2550	473	Potted	2741	324
H-2	3007	518	2825	532	3110	519	Potted	2981	144
H-3	2731	578	2899	613	2756	570	Coated	2795	90
A31108	3372	587	3169	634	3125	604	(Coated	3222	132
A30433	2549	586	2778	605	2882	596	From	2736	170
A22719	3196	596	2954	569	3020	572	TR-317( )	3057	125
A24394	2998	593	3142	579	3057	772	Autopsies)	3066	72

Table 1b - TR-317( ) Autotransformers from GE (made by Chloride).

		Relative Freq		Relative Freq		Relative Freq		CIV	
Ser #	CIV	(Hz)	CIV	(Hz)	CIV	(Hz)	Type	Mean	Std Dev
1	3152	509	3199	596	3267	597	Coated	3206	58
2	3428	501	3137	617	3203	616	with corona	3256	153
3	3056	515	3200	609	3175	608	suppressant	3144	77
4	3247	620	3105	619	3050	619	*	3134	102
5	3007	624	3109	623	3135	624		3084	68
6	3108	620	3013	621	3135	618		3085	64

* Hi Temp 221, Hi Temp Resins Inc.

Table 1c - TR-317R Sample Buy Autotransformers from Harder Inc.

		Relative Freq		Relative Freq		Relative Freq		CIV	
Ser #	CIV	(Hz)	CIV	(Hz)	CIV	(Hz)	Type	Mean	Std Dev
037	2581	576	2564	577	2581	577	Coated	2575	10
041	2522	570	2479	569	2526	569	with	2509	26
054	3003	571	3100	568	3044	569	epoxy	3049	49
058	2570	568	2605	569	2500	568	resin	2558	53
060	2570	582	2500	582	2580	582	as per	2550	44
061	2700	579	2816	578	2703	579	dwg pkg	2760	66

Table 2 provides corona inception data for several TR-330A transformers. The test circuit shown in Fig. 1 was used to take the data with the following modifications: Capacitor CA was changed to 3000 pF and the power amplifier was a McIntosh Model 2500. The frequencies shown in Table 2 are, in this case, the actual resonance frequencies.

Table 2 - TR-330A Autotransformer Corona Test Data.

								CIV	
		Freq		Freq		Freq			Std
Ser #	CIV	(Hz)	CIV	(Hz)	CIV	(Hz)	Type	Mean	Dev
1	1504	6925	1500	6922	1513	6922	Ferrite	1506	7.0
2	1526	6944	1568	6948	1540	6950	Ferrite	1545	21
3	1500	6942	1517	6945	1522	6942	Ferrite	1513	12
194	1559	6583	1587	6582	1590	6582	Ferrite	1579	17
567	1583	7152	1548	7148	1597	7150	Ferrite	1576	25
617	1559	7088	1556	7087	1560	7086	Ferrite	1558	2.1
MPP 1*	530	6543	600	6531	596	6534	Unpotted	575	39
MPP 2*	1659	6302	1644	6282	1652	6288	Potted	1652	7.5
MPP 3*	545	6533	585	6526	562	6527	Unpotted	564	20
MPP 4*	1655	6235	1650	6234	1659	6235	Potted	1655	4.5

* MPP 1 = Unpotted toroid 55251-W4 core.
MPP 2 = Potted toroid 55251-W4 core.
MPP 3 = Unpotted toroid 55248-A2 core.
MPP 4 = Potted toroid 55248-A2 core.
MPP = Molypermalloy Powder core manufactured by Magnetics Inc.
Potting compound = Eccobond 45 black with 19M catalyst. Autotransformer was vacuum potted.

CONCLUSIONS

The data from both the TR-330A, TR-317( ), TR-317R, and the TR-317 autotransformer samples indicate that the TR-330A representatives have a smaller standard deviation than representatives from the TR-317 group. In particular, serial #H-1 of the TR-317 group, with a standard deviation of 324 V, presents an interesting problem. Operator error is the most probable cause of the first excessively high CIV reading for serial #H-1, as the last two readings are much closer to each other (within 7 V). Standard deviations were below 6% of the mean CIV recorded. For this type of measurement, the standard deviations are acceptable. An AM receiver was added to the rest of the ancillary equipment co gather the TR-330A data where the standard dcviations were less than 2% of the mean CIV. The AM receiver has the advantage of providing the operator with an audio reference which compliments the visual reference.

SUMMARY

An autotransformer corona test circuit has been developed and tested, ancillary equipment for the test has been identified and recommended, test procedures and precautions have been presented, and measured corona data are presented for autotransformers of different manufacture and type. As a result, recommendations have been made to NAVSEA to incorporate the test into appropriate drawing packages.

ACKNOWLEDGMENTS

The authors wish to express appreciation to Homer Ding of NOSC, San Diego, CA, for his work on the computer program and for his guidance, and to Leo Johnson, also of NOSC, for his guidance.

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3. R.W. Timme and J.F. Cartier, "NAVSEA TRANSDUCER IMPROVEMENT PROGRAM (NTIP), FY88 Fourth Quarter Progress Report," NRL Memorandum Report No. 6371 (Oct 1988).

Appendix

LADDER COMPUTER PROGRAM FOR EMI FILTER

Figure A1 contains the circuit identifiers used to operate the computer program which follows. This program was used successfully on a Hewlett Packard 9000, model 200 computer using HP BASIC 5.0. Lines 80-120 in the program describe the initial procedure of loading the program.

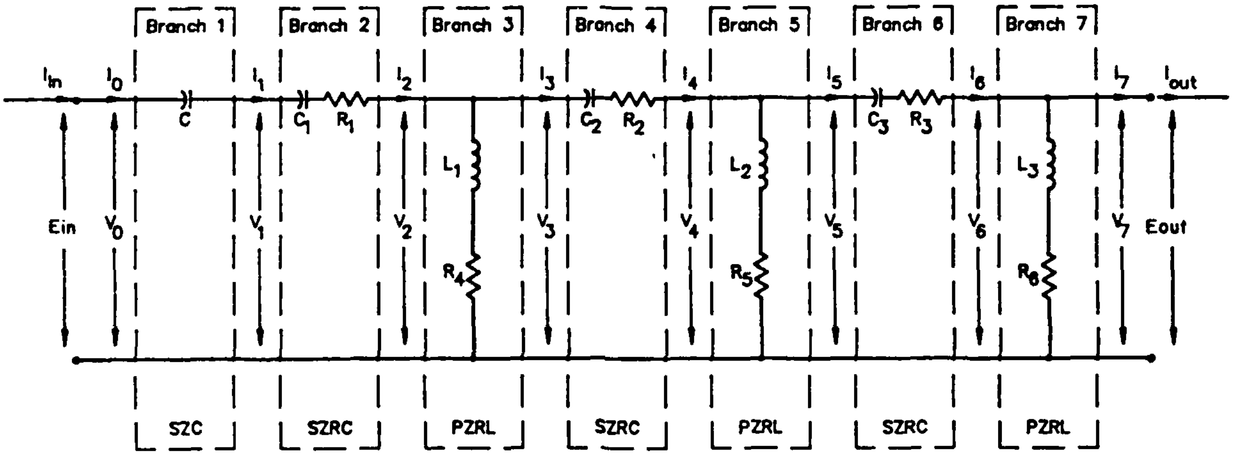

Fig. A1 - Circuit identifiers.

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10             ! LADDER PROGRAM  VERSION 1.0, OCTOBER 1988
20             ! AUTHOR:  HOMER DING
30             !          NAVAL OCEAN SYSTEMS CENTER
40             !          CODE 711, BLDG 132
50             !          SAN DIEGO, CA.  92152
60             !          (619) 553-1443
70             !
80             ! THIS PROGRAM WAS WRITTEN IN HP BASIC 4.0.
90             ! A COMPLEX EXTENSION FROM STRUCTURED SOFTWARE SYSTEMS
100            ! WAS ALSO USED.
110            ! THIS PROGRAM SHOULD WORK WITH HP BASIC 5.0 IF THE GET STATEMENT
120            ! IS USED TO PLACE THE ASCII FILE IN THE COMPUTER.
130            !
140            ! THIS PROGRAM WILL COMPUTE THE OUTPUT/INPUT VOLTAGE TRANSFER FUN
CTION
150            ! OF A LADDER NETWORK.
160            ! Nb = TOTAL NUMBER OF BRANCHES
170            ! THE FIRST LETTER OF A BRANCH TYPE IS S, P, OR T
180            ! S = SERIES BRANCH
190            ! P = PARALLEL BRANCH
200            ! T = IDEAL TRANSFORMER
210            ! IF T THEN THERE ARE NO OTHER LETTERS WHICH DESCRIBES THE BRANCH
 TYPE
220            ! Z = SERIES COMBINATION OF BRANCH COMPONENTS
230            ! Y = PARALLEL COMJBINATION OF BRANCH COMPONENTS
240            ! C, L, AND R = TYPE OF BRANCH COMPONENTS
250            !
260            COM /Menu/ Menu$(20)[80],Ch$(20)[6],Mark0$[1],Mark1$[1],INTEGER N
ent,Nchr,Xtab,Ytab,Ch(20)
270            COM /N/ @Path1,Netfile$[20],Cmnt$(2)[80],Br$(20)[6],INTEGER Nb,RE
AL R(20),L(20),C(20),Clk$[80]
280            COM /C/ REAL F,W,F1,F2,Fs,Swpsegs(6,4),INTEGER Nseg,Ns,Tns,Logflg
,Logflags(6),COMPLEX Eb(20),Ib(20),Imb(20),Yb(20),Anet(2,2)
290            COM /Lj/ Lf$[1],Cr$[1],Ff$[3],Esc$[1],Portrait$[6],Landscaqpe$[6]
,Font$(4)[80],INTEGER Psc,Page,Npages,Fontnum
300            INTEGER Chose,M,K1,K2,I
310            REAL X,Y,G,B,Z,Mag,Ang
320            DIM S$[80],K$[2]
330            LOCAL 7
340            Lf$=CHR$(10)
350            Cr$=CHR$(13)
360            Esc$=CHR$(27)
370            Ff$=Esc$&CHR$(7)&CHR$(12)
380            Portrait$=Esc$&"&100"
390            Portrait$=Esc$&"&110"
400            Font$(1)=Portrait$&Esc$&"(10U"&Esc$&"(s0p10.00h12.00v0s0B"&Esc$&"
&16D"
410            Font$(2)=Landscape$&Esc$&"(10U"&Esc$&"(s0p10.00h12.00v0s0B"&Esc$&
"&16D"
420            Font$(3)=P0rtrait$&Esc$&"(10U"&Esc$&"(s0p16.66h8.50v0s-3B"&Esc$&"
&15.6667C"
430            Font$(4)=Landscape$&Esc$&"(10U"&Esc$&"(s0p16.66h8.50v0s-3B"&Esc$&
"&15.6667C"
440            REPEAT
```

```
450               CALL Menu(1)
460               CALL Cls
470               SELECT Ch$(1)
480               CASE "G"
490                  CALL Getnfile
500               CASE "E"
510                  CALL Entnet
520               CASE "S"
530                  CALL Recnfile
540               CASE "P"
550                  CALL Entint("PRINTER SELECT CODE(1=CRT, 2=THINKJET, 9=LASER
 JET)",Psc)
560                  Clk$[1,80]=FNClock$
570                  CALL Prtnet
580               CASE "F"
590                  CALL Entswpsegs
600               CASE "R"
610                  CALL Entint("PRINTER SELECT CODE(1=CRT, 2=THINKJET, 9=LASER
 JET)",Psc)
620                  Clk$[1,80]=FNClock$
630                  CALL Prtrat
640               CASE "I"
650                  CALL Entint("PRINTER SELECT CODE(1=CRT, 2=THINKJET, 9=LASER
 JET)",Psc)
660                  Clk$[1,80]=FNClock$
670                  CALL Prtlev
680               CASE "A"
690                  CALL Entint("PRINTER SELECT CODE(1=CRT, 2=THINKJET, 9=LASER
 JET)",Psc)
700                  Clk$[1,80]=FNClock$
710                  CALL Prtanet
720               END SELECT
730            UNTIL Ch(1)=Nent
740            CALL Cls
750            STOP
760            END
770            !
780            SUB Beep(OPTIONAL INTEGER Nbeep,Freq,REAL Secon,Secof)
790               INTEGER I,F,N
800               REAL S1,S0
810               N=1
820               F=2700
830               S1=.03
840               S0=.04
850               IF NPAR>0 THEN N=Nbeep
860               IF NPAR>1 THEN F=Freq
870               IF NPAR>2 THEN S1=Secon
880               IF NPAR>3 THEN S0=Secof
890               FOR I=1 TO N
900                  BEEP F,S1
910                  WAIT S0
920               NEXT I
930            SUBEND ! Beep
940            !
```

```
950     SUB Fkeys(OPTIONAL INTEGER Keyon) !0=OFF, 1=ON
960        INTEGER K
970        K=1
980        IF NPAR=1 THEN K=NOT Keyon
990        CONTROL CRT,12;K
1000    SUBEND ! Fkeys
1010    !
1020    SUB Curs(OPTIONAL INTEGER Col,Row,Curson)
1030       INTEGER C,R,S
1040       C=1
1050       R=19
1060       S=1 ! CURS ON
1070       IF NPAR>0 THEN C=Col
1080       IF NPAR>1 THEN R=Row
1090       IF NPAR>2 THEN S=Curson
1100       CONTROL CRT,0;C
1110       CONTROL CRT,1;R
1120       CONTROL CRT,10;S
1130    SUBEND ! Curs
1140    !
1150    SUB Cls(OPTIONAL INTEGER Col,Row,Keyof)
1160       INTEGER C,R,K
1170       C=1
1180       R=19
1190       K=0
1200       IF NPAR>0 THEN C=Col
1210       IF NPAR>1 THEN R=Row
1220       IF NPAR>2 THEN K=Keyof
1230       OUTPUT CRT;CHR$(128);
1240       OUTPUT KBD;CHR$(255)&"K";
1250       CALL Fkeys(K)
1260       CALL Curs(C,R)
1270    SUBEND ! Cls
1280    !
1290    DEF FNClock$
1300       RETURN UPC$(DATE$(TIMEDATE)&", "&TIME$(TIMEDATE))
1310    FNEND ! FNClock$
1320    !
1330    SUB Continue
1340       INTEGER K1,K2
1350       DISP "TO CONTINUE HIT ANY KEY"
1360       CALL Kbscan(K1,K2)
1370       DISP
1380    SUBEND ! Continue
1390    !
1400    DEF FNAtn2(X,Y,OPTIONAL INTEGER Posang) ! 4 QUADRANT ARC TANGENT
1410       INTEGER P
1420       DEG
1430       P=0
1440       IF NPAR=3 THEN P=Posang
1450       RETURN ARG(CMPLX(X,Y))+(P<>0)*360
1460    FNEND ! FNAtn2
1470    !
1480    SUB Rec2pol(Xr,Xi,Mag,Ang,OPTIONAL INTEGER Posang)
```

```
1490     INTEGER P
1500     REAL M
1510     DEG
1520     P=0
1530     IF NPAR=5 THEN P=Posang
1540     M=ABS(CMPLX(Xr,Xi))
1550     Ang=FNAtn2(Xr,Xi,P)
1560     Mag=M
1570  SUBEND ! Rec2pl
1580  !
1590  SUB Pol2rec(Mag,Ang,Xr,Xi)      !POLAR TO RECTANGULAR
1600     REAL Txr
1610     Txr=Mag*COS(Ang)
1620     Xi=Mag*SIN(Ang)
1630     Xr=Txr
1640  SUBEND ! Pol2rec
1650  !
1660  DEF FNDb(X)
1670     RETURN 20*LGT(X)
1680  FNEND ! FNDb
1690  !
1700  DEF FNAdb(X)
1710     RETURN 10^(.05*X)
1720  FNEND ! FNAdb
1730  !
1740  SUB Entstr(Prompt$,Str$)
1750     DIM Temp$[80]
1760     DISP Prompt$&" = ";
1770     OUTPUT 2;Str$;
1780     OUTPUT KBD;CHR$(255);"H";
1790     LINPUT Temp$
1800     IF Temp$<>"" THEN Str$=Temp$
1810     PRINT Prompt$&" = ";Str$
1820  SUBEND ! EntSTR
1830  !
1840  SUB Entint(Prompt$,INTEGER I,OPTIONAL INTEGER Noprt)
1850     DIM Temp$[80]
1860     INTEGER Prtflg
1870     Prtflg=1
1880     IF NPAR=3 THEN Prtflg=NOT Noprt
1890     DISP Prompt$&" = ";
1900     OUTPUT 2;VAL$(I);
1910     OUTPUT KBD;CHR$(255);"H";
1920     LINPUT Temp$
1930     IF Temp$<>"" THEN I=VAL(Temp$)
1940     IF Prtflg THEN PRINT Prompt$&" = ";I
1950  SUBEND ! Entint
1960  !
1970  SUB Entreal(Prompt$,REAL V,OPTIONAL REAL Unitmult)
1980     REAL U
1990     DIM Temp$[80]
2000     U=1
2010     IF NPAR=3 THEN U=Unitmult
2020     DISP Prompt$&" = ";
```

```
2030              OUTPUT 2;VAL$(V/U);
2040              OUTPUT KBD;CHR$(255);"H";
2050              LINPUT Temp$
2060              IF Temp$<>"" THEN V=VAL(Temp$)*U
2070              PRINT Prompt$&" = ";V/U
2080           SUBEND ! Entreal
2090           !
2100           SUB Prtmenu(INTEGER Nmenu)
2110              COM /Menu/ Menu$(20)[80],Ch$(20)[6],Mark0$[1],Mark1$[1],INTEGE
R Nent,Nchr,Xtab,Ytab,Ch(20)
2120              PRINTER IS CRT
2130              SELECT Nmenu
2140              CASE 1
2150                 RESTORE Menu1
2160              CASE 2
2170                 RESTORE Menu2
2180              CASE 3
2190                 RESTORE Menu3
2200              END SELECT ! Nmenu
2210              CALL Cls
2220              ALPHA OFF
2230              READ Menu$(0)
2240              READ Nent
2250              READ Nchr
2260              Mxlen=0
2270              FOR I=1 TO Nent
2280                 READ Menu$(I)
2290                 Mxlen=MAX(Mxlen,LEN(Menu$(I)))
2300              NEXT I
2310              Xtab=INT(.5*(80-Mxlen))+1
2320              Ytab=18-Nent
2330              PRINT TABXY(Xtab+Nchr+2,Ytab-1);Mark0$&Menu$(0)
2340              FOR I=1 TO Nent
2350                 PRINT TABXY(Xtab,Ytab+I);Mark0$&Menu$(I)
2360              NEXT I
2370              SUBEXIT
2380              !
2390 Menu1:       DATA "LADDER NETWORK PROGRAM",9,1
2400              DATA G  GET DATA FROM DISK
2410              DATA E  ENTER NETWORK
2420              DATA S  SAVE DATA TO DISK
2430              DATA P  PRINT NETWORK
2440              DATA F  ENTER FREQUENCY SWEEP
2450              DATA A  PRINT A MATRIX
2460              DATA R  PRINT I/O RATIOS
2470              DATA I  PRINT INTERNAL LEVELS
2480              DATA Q  QUIT
2490              !
2500 Menu2:       DATA MAIN PLOT MENU,9,1
2510              DATA I  INITIALIZE FOR PLOTING
2520              DATA T  ENTER TYPE OF PLOT
2530              DATA N  ENTER NAMES FOR PLOT AND AXES
2540              DATA S  ENTER SCALES
2550              DATA L  ENTER LEGEND
```

```
2560               DATA A  PLOT AXES
2570               DATA D  PLOT DATA
2580               DATA +  ADD TO FILE NUMBERS
2590               DATA Q  QUIT
2600               !
2610            SUBEND ! Prtmenu
2620            !
2630            SUB Kbscan(INTEGER K1,K2,OPTIONAL K$)
2640               DIM Ch$[2]
2650               K1=0
2660               ON KBD GOSUB Kbintr
2670               REPEAT
2680               UNTIL K1<>0
2690               OFF KBD
2700               SUBEXIT
2710               !
2720 Kbintr:       Ch$=KBD$
2730               K1=NUM(Ch$[1,1])
2740               IF K1=255 THEN
2750                  K2=NUM(Ch$[2,2])
2760                  Ch$=Ch$[2,2]
2770               ELSE
2780                  K2=0
2790               END IF
2800               IF NPAR=3 THEN K$=Ch$
2810               RETURN
2820            SUBEND ! Kbscan
2830            !
2840            SUB Menu(INTEGER Nmenu)
2850               COM /Menu/ Menu$(20)[80],Ch$(20)[6],Mark0$[1],Mark1$[1],INTEGE
R Nent,Nchr,Xtab,Ytab,Ch(20)
2860               INTEGER I,K1,K2,Wdth,Chose,Xtm1
2870               DIM K$[2]
2880               Mark0$=CHR$(128)
2890               Mark1$=CHR$(129)
2900               CALL Prtmenu(Nmenu)
2910               Chose=Ch(Nmenu)
2920               Xtm1=Xtab-1
2930               DISP "SELECT WITH ALPHA-NUMERIC OR UP-DOWN KEYS, THEN HIT RETU
RN"
2940               REPEAT
2950 Scan:            IF Chose<1 THEN Chose=Nent
2960                  IF Chose>Nent THEN Chose=1
2970                  PRINT TABXY(Xtm1,Ytab+Chose);Mark1$&" "&Menu$(Chose)&" ";
2980                  CALL Kbscan(K1,K2,K$)
2990                  PRINT TABXY(Xtm1,Ytab+Chose);Mark0$&" "&Menu$(Chose)&" ";
3000                  IF K1<>255 THEN
3010                     GOSUB Search
3020                  ELSE
3030                     IF K2<>69 THEN Chose=Chose+(K2=86)-(K2=94)
3040                  END IF
3050               UNTIL K1=255 AND K2=69
3060               Ch(Nmenu)=Chose
3070               Ch$(Nmenu)=Menu$(Chose)[1,Nchr]
```

```
3080              DISP
3090              SUBEXIT
3100              !
3110 Search:      FOR I=1 TO Nent
3120                IF K$=Menu$(I)[1,1] THEN
3130                  Chose=I
3140                  I=Nent
3150                END IF
3160              NEXT I
3170              RETURN
3180              !
3190            SUBEND ! Menu
3200            !
3210            SUB Tboxon
3220              Lj$="CALL 25CE,1"&CHR$(13)
3230              OUTPUT 9;"QUIET ON"&CHR$(13);
3240              OUTPUT 9;Lj$;
3250            SUBEND ! Tboxon
3260            !
3270            SUB Tboxoff
3280              Quit$=CHR$(27)&CHR$(127)&"DONE"&CHR$(13)&CHR$(13)
3290              OUTPUT 9;Quit$;
3300              WAIT 1
3310              OUTPUT 9;"QUIET OFF"&CHR$(13);
3320            SUBEND ! Tboxoff
3330            !
3340            SUB Preprint
3350              COM /Lj/ Lf$[1],Cr$[1],Ff$[3],Esc$[1],Portrait$[6],Landscaqpe$
[6],Font$(4)[80],INTEGER Psc,Page,Npages,Fontnum
3360              PRINTER IS Psc
3370              IF Psc=9 THEN
3380                OUTPUT Psc;Esc$&CHR$(7)&"Q0;";! GO TO LASERJET SERIES II EM
ULATION
3390                WAIT 1.5
3400                OUTPUT Psc;Font$(Fontnum);
3410                OUTPUT Psc;Esc$&"&a10L";! SET LEFT MARGIN 10 SPAACES
3420                OUTPUT Psc;Esc$&"&s0C";! SET LINE WRAP
3430              END IF
3440            SUBEND ! Preprint
3450            !
3460            SUB Postprint
3470              COM /Lj/ Lf$[1],Cr$[1],Ff$[3],Esc$[1],Portrait$[6],Landscaqpe$
[6],Font$(4)[80],INTEGER Psc,Page,Npages,Fontnum
3480              IF Psc=CRT THEN
3490                CALL Continue
3500              ELSE
3510                OUTPUT Psc;Ff$;
3520              END IF
3530              CALL Beep(5)
3540            SUBEND ! Postprint
3550            !
3560            SUB Llist
3570              COM /Lj/ Lf$[1],Cr$[1],Ff$[3],Esc$[1],Portrait$[6],Landscaqpe$
[6],Font$(4)[80],INTEGER Psc,Page,Npages,Fontnum
```

```
3580                 CALL Entint("PRINTER SELECT CODE(1=CRT, 2=THINKJET, 9=LASERJET
)",Psc)
3590                 File$="LADDER"
3600                 Page=0
3610                 Npages=0
3620                 Fontnum=3
3630                 CALL Preprint
3640                 CAT File$
3650                 CALL Postprint
3660                 CALL Continue
3670                 CALL Preprint
3680                 LIST #Psc
3690                 CALL Postprint
3700                 CALL Beep(5)
3710              SUBEND ! Llist
3720              !
3730              SUB Record(OPTIONAL INTEGER A)
3740                 File$="LADDER"
3750                 IF NPAR>0 THEN
3760                    RE-SAVE File$&":,702,0"
3770                    DISP """"&File$&""" PROGRAM RE-SAVED IN ASCII FORMAT";TAB(8
0)
3780                 ELSE
3790                    RE-STORE File$&":,1400"
3800                    DISP """"&File$&""" PROGRAM RE-STORED IN INTERNAL FORMAT";T
AB(80)
3810                 END IF
3820                 CALL Beep(5)
3830              SUBEND ! Record
3840              !
3850              DEF FNExist(Name$)
3860                 INTEGER Existflg
3870                 Existflg=1
3880                 ON ERROR RECOVER Er
3890                 ASSIGN @P TO Name$
3900 R:              IF Existflg THEN ASSIGN @P TO *
3910                 OFF ERROR
3920                 RETURN Existflg
3930                 !
3940 Er:             Existflg=0
3950                 GOTO R
3960                 !
3970              FNEND ! FNExist
3980              !
3990              SUB Mknet
4000                 COM /N/ @Path1,Netfile$[20],Cmnt$(2)[80],Br$(20)[6],INTEGER Nb
,REAL R(20),L(20),C(20),Clk$[80]
4010                 CREATE BDAT Netfile$,4
4020              SUBEND ! Mknet
4030              !
4040              SUB Getnfile
4050                 COM /N/ @Path1,Netfile$[20],Cmnt$(2)[80],Br$(20)[6],INTEGER Nb
,REAL R(20),L(20),C(20),Clk$[80]
4060                 INTEGER Flg
```

```
4070             REPEAT
4080                CALL Entstr("NETWORK FILE NAME",Netfile$)
4090                Flg=FNExist(Netfile$)
4100                IF Flg=0 THEN
4110                   BEEP
4120                   PRINT """";Netfile$;""" DOESN'T EXIST, TRY AGAIN"
4130                END IF
4140             UNTIL Flg
4150             ASSIGN @Path1 TO Netfile$
4160             ENTER @Path1;Cmnt$(*),Nb,Br$(*),R(*),C(*),L(*)
4170             ASSIGN @Path1 TO *
4180          SUBEND ! Getnfile
4190          !
4200          SUB Recnfile
4210             COM /N/ @Path1,Netfile$[20],Cmnt$(2)[80],Br$(20)[6],INTEGER Nb
,REAL R(20),L(20),C(20),Clk$[80]
4220             CALL Entstr("NETWORK FILE NAME",Netfile$)
4230             IF FNExist(Netfile$)=0 THEN CALL Mknet
4240             ASSIGN @Path1 TO Netfile$
4250             OUTPUT @Path1;Cmnt$(*),Nb,Br$(*),R(*),C(*),L(*)
4260             ASSIGN @Path1 TO *
4270          SUBEND ! Recnfile
4280          !
4290          SUB Entnet
4300             COM /N/ @Path1,Netfile$[20],Cmnt$(2)[80],Br$(20)[6],INTEGER Nb
,REAL R(20),L(20),C(20),Clk$[80]
4310             INTEGER I
4320             DIM S$[40],T$[12]
4330 Format1:    IMAGE "BRANCH ",K,#
4340             CALL Cls
4350             CALL Entstr("REM 1",Cmnt$(1))
4360             CALL Entstr("REM 2",Cmnt$(2))
4370             CALL Entint("NUMBER OF BRANCHES",Nb)
4380             FOR I=1 TO Nb
4390                OUTPUT S$ USING Format1;I
4400                T$=Br$(I)
4410                CALL Entstr(S$&" TYPE",T$)
4420                Br$(I)=T$
4430                IF T$[1,1]="X" OR T$[1,1]="T" THEN CALL Entreal("TRANSFORME
R TURNS RATIO (NS/NP)",R(I))
4440                IF POS(T$,"R")<>0 THEN CALL Entreal(S$&" R (KOHM)",R(I),1.E
+3)
4450                IF POS(T$,"C")<>0 THEN CALL Entreal(S$&" C (nF)",C(I),1.E-9
)
4460                IF POS(T$,"L")<>0 THEN CALL Entreal(S$&" L (mH)",L(I),1.E-3
)
4470             NEXT I
4480          SUBEND ! Entnet
4490          !
4500          SUB Seg2f(INTEGER S)
4510             COM /C/ REAL F,W,F1,F2,Fs,Swpsegs(6,4),INTEGER Nseg,Ns,Tns,Log
flg,Logflags(6),COMPLEX Eb(20),Ib(20),Imb(20),Yb(20),Anet(2,2)
4520             F1=Swpsegs(S,1)
4530             F2=Swpsegs(S,2)
```

```
4540                 Fs=Swpsegs(S,3)
4550                 Ns=Swpsegs(S,4)
4560                 Logflg=Logflags(S)
4570              SUBEND ! Seg2f
4580              !
4590              SUB F2seg(INTEGER S)
4600                 COM /C/ REAL F,W,F1,F2,Fs,Swpsegs(6,4),INTEGER Nseg,Ns,Tns,Log
flg,Logflags(6),COMPLEX Eb(20),Ib(20),Imb(20),Yb(20),Anet(2,2)
4610                 Swpsegs(S,1)=F1
4620                 Swpsegs(S,2)=F2
4630                 Swpsegs(S,3)=Fs
4640                 Swpsegs(S,4)=Ns
4650                 Logflags(S)=Logflg
4660              SUBEND ! F2seg
4670              !
4680              SUB Entswp(S$)
4690                 COM /C/ REAL F,W,F1,F2,Fs,Swpsegs(6,4),INTEGER Nseg,Ns,Tns,Log
flg,Logflags(6),COMPLEX Eb(20),Ib(20),Imb(20),Yb(20),Anet(2,2)
4700                 CALL Entint(S$&"SWEEP TYPE (0=LINEAR, 1=LOG)",Logflg)
4710                 CALL Entreal(S$&"FIRST FREQUENCY (Hz)",F1)
4720                 CALL Entreal(S$&"LAST FREQUENCY (Hz)",F2)
4730                 SELECT Logflg
4740                 CASE 0 ! LINEAR SWEEP
4750                    CALL Entreal(S$&"STEP FREQUENCY (Hz)",Fs)
4760                    IF Fs=0 THEN
4770                       CALL Entint(S$&"NUMBER OF STEPS",Ns)
4780                       Fs=(F2-F1)/(N-1)
4790                    ELSE
4800                       Ns=((F2-F1)/Fs)+1
4810                    END IF
4820                 CASE 1 ! LOG SWEEP
4830                    CALL Entint(S$&"NUMBER OF STEPS",Ns)
4840                    Fs=(F2/F1)^(1/(Ns-1))
4850                 END SELECT
4860              SUBEND ! Entswp
4870              !
4880              SUB Compimb(INTEGER Bi)
4890                 COM /N/ @Path1,Netfile$[20],Cmnt$(2)[80],Br$(20)[6],INTEGER Nb
,REAL R(20),L(20),C(20),Clk$[80]
4900                 COM /C/ REAL F,W,F1,F2,Fs,Swpsegs(6,4),INTEGER Nseg,Ns,Tns,Log
flg,Logflags(6),COMPLEX Eb(20),Ib(20),Imb(20),Yb(20),Anet(2,2)
4910                 INTEGER Ps,Pp,Py,Pz,Pr,Pl,Pc
4920                 REAL Xr,Xi
4930                 Ps=POS(Br$(Bi),"S")
4940                 Pp=POS(Br$(Bi),"P")
4950                 Pz=POS(Br$(Bi),"Z")
4960                 Py=POS(Br$(Bi),"Y")
4970                 Pr=POS(Br$(Bi),"R")
4980                 Pl=POS(Br$(Bi),"L")
4990                 Pc=POS(Br$(Bi),"C")
5000                 Xr=0
5010                 Xi=0
5020                 W=(PI+PI)*F
5030                 IF Pz<>0 THEN
```

```
5040                     IF Pr<>0 THEN Xr=R(Bi)
5050                     IF Pl<>0 THEN Xi=Xi+W*L(Bi)
5060                     IF Pc<>0 THEN Xi=Xi-1/(W*C(Bi))
5070                  END IF
5080                  IF Py<>0 THEN
5090                     IF Pr<>0 THEN Xr=1/R(Bi)
5100                     IF Pl<>0 THEN Xi=Xi-1/(W*L(Bi))
5110                     IF Pc<>0 THEN Xi=Xi+W*C(Bi)
5120                  END IF
5130                  Imb(Bi)=CMPLX(Xr,Xi)
5140                  IF (Ps<>0 AND Py<>0) OR (Pp<>0 AND Pz<>0) THEN Imb(Bi)=1/Imb(B
i)
5150               SUBEND ! CompimbEDIT4530
5160               !
5170               SUB Cascade
5180                  COM /N/ @Path1,Netfile$[20],Cmnt$(2)[80],Br$(20)[6],INTEGER Nb
,REAL R(20),L(20),C(20),Clk$[80]
5190                  COM /C/ REAL F,W,F1,F2,Fs,Swpsegs(6,4),INTEGER Nseg,Ns,Tns,Log
flg,Logflags(6),COMPLEX Eb(20),Ib(20),Imb(20),Yb(20),Anet(2,2)
5200                  INTEGER I
5210                  Anet(1,1)=CMPLX(1,0)
5220                  Anet(1,2)=CMPLX(0,0)
5230                  Anet(2,1)=Anet(1,2)
5240                  Anet(2,2)=Anet(1,1)
5250                  FOR I=Nb TO 1 STEP -1
5260                     CALL Compimb(I)
5270                     SELECT Br$(I)[1,1]
5280                     CASE "T","X"
5290                        Anet(1,1)=Anet(1,1)/R(I)
5300                        Anet(1,2)=Anet(1,2)/R(I)
5310                        Anet(2,1)=Anet(2,1)*R(I)
5320                        Anet(2,2)=Anet(2,2)*R(I)
5330                     CASE "S"
5340                        Anet(1,1)=Anet(1,1)+Imb(I)*Anet(2,1)
5350                        Anet(1,2)=Anet(1,2)+Imb(I)*Anet(2,2)
5360                     CASE "P"
5370                        Anet(2,1)=Anet(2,1)+Imb(I)*Anet(1,1)
5380                        Anet(2,2)=Anet(2,2)+Imb(I)*Anet(1,2)
5390                     END SELECT
5400                  NEXT I
5410               SUBEND ! Cascade
5420               !
5430               SUB Compeiy
5440                  COM /N/ @Path1,Netfile$[20],Cmnt$(2)[80],Br$(20)[6],INTEGER Nb
,REAL R(20),L(20),C(20),Clk$[80]
5450                  COM /C/ REAL F,W,F1,F2,Fs,Swpsegs(6,4),INTEGER Nseg,Ns,Tns,Log
flg,Logflags(6),COMPLEX Eb(20),Ib(20),Imb(20),Yb(20),Anet(2,2)
5460                  INTEGER I,Im1
5470                  Yb(Nb)=CMPLX(0,0)
5480                  Ib(Nb)=Yb(Nb)
5490                  Eb(Nb)=CMPLX(1,0)
5500                  FOR I=Nb TO 1 STEP -1
5510                     Im1=I-1
5520                     CALL Compimb(I)
```

```
5530                    SELECT Br$(I)[1,1]
5540                    CASE "T","X"
5550                       Eb(Im1)=Eb(I)/R(I)
5560                       Ib(Im1)=Ib(I)*R(I)
5570                    CASE "S"
5580                       Eb(Im1)=Eb(I)+Ib(I)*Imb(I)
5590                       Ib(Im1)=Ib(I)
5600                    CASE "P"
5610                       Eb(Im1)=Eb(I)
5620                       Ib(Im1)=Eb(I)*Imb(I)+Ib(I)
5630                    END SELECT
5640                 NEXT I
5650              SUBEND ! Compeiy
5660              !
5670              SUB Prth
5680                 COM /N/ @Path1,Netfile$[20],Cmnt$(2)[80],Br$(20)[6],INTEGER Nb
,REAL R(20),L(20),C(20),Clk$[80]
5690                 COM /Lj/ Lf$[1],Cr$[1],Ff$[3],Esc$[1],Portrait$[6],Landscaqpe$
[6],Font$(4)[80],INTEGER Psc,Page,Npages,Fontnum
5700                 IF Page>0 THEN
5710                    IF Npages=0 THEN
5720                       PRINT Clk$[1,61+10*(F>2)]&"PAGE "&VAL$(Page)
5730                    ELSE
5740                       PRINT Clk$[1,55+10*(F>2)]&"PAGE "&VAL$(Page)&" OF "&VAL$
(Npages)
5750                    END IF
5760                 END IF
5770                 IF NOT (Cmnt$(1)[1,1]=" " OR LEN(Cmnt$(1))=0) THEN PRINT Cmnt$
(1)
5780                 IF NOT (Cmnt$(2)[1,1]=" " OR LEN(Cmnt$(2))=0) THEN PRINT Cmnt$
(2)
5790                 PRINT
5800              SUBEND ! Prth
5810              !
5820              SUB Prtnet
5830                 COM /N/ @Path1,Netfile$[20],Cmnt$(2)[80],Br$(20)[6],INTEGER Nb
,REAL R(20),L(20),C(20),Clk$[80]
5840                 COM /Lj/ Lf$[1],Cr$[1],Ff$[3],Esc$[1],Portrait$[6],Landscaqpe$
[6],Font$(4)[80],INTEGER Psc,Page,Npages,Fontnum
5850                 INTEGER I
5860 Fmt1:           IMAGE "BR   TYPE        R (KOHM)          L (mH)           C
 (nF)   TURNS RATIO(S/P)"
5870 Fmt2:           IMAGE DD,3X,AAAAAA,#
5880 Fmt3:           IMAGE 6X,DDDDD.DDDDD,#
5890 Fmt4:           IMAGE "      -----------",#
5900 Fmt5:           IMAGE 4X,DDDDD.DDDDD,#
5910 Fmt6:           IMAGE 4X,"-----------",#
5920 Fmt7:           IMAGE "PRINTING PAGE ",K," OF ",K
5930                 IF Psc=9 THEN
5940                    Fontnum=3
5950                 ELSE
5960                    Fontnum=0
5970                 END IF
5980                 CALL Preprint
```

```
5990                Page=1
6000                Npages=1
6010                CALL Prth
6020                IF Psc<>CRT THEN OUTPUT CRT USING Fmt7;Page,Npages
6030                PRINT USING Fmt1
6040                FOR I=1 TO Nb
6050                  PRINT USING Fmt2;I,Br$(I)
6060                  IF POS(Br$(I),"R")<>0 THEN
6070                    PRINT USING Fmt3;R(I)*1.E-3
6080                  ELSE
6090                    PRINT USING Fmt4
6100                  END IF
6110                  IF POS(Br$(I),"L")<>0 THEN
6120                    PRINT USING Fmt3;L(I)*1.E+3
6130                  ELSE
6140                    PRINT USING Fmt4
6150                  END IF
6160                  IF POS(Br$(I),"C")<>0 THEN
6170                    PRINT USING Fmt3;C(I)*1.E+9
6180                  ELSE
6190                    PRINT USING Fmt4
6200                  END IF
6210                  IF POS(Br$(I),"T")<>0 OR POS(Br$(I),"X")<>0 THEN
6220                    PRINT USING Fmt5;R(I)
6230                  ELSE
6240                    PRINT USING Fmt6
6250                  END IF
6260                  PRINT
6270                NEXT I
6280                CALL Postprint
6290              SUBEND ! Prtnet
6300              !
6310              SUB Prtrat
6320                COM /N/ @Path1,Netfile$[20],Cmnt$(2)[80],Br$(20)[6],INTEGER Nb
,REAL R(20),L(20),C(20),Clk$[80]
6330                COM /C/ REAL F,W,F1,F2,Fs,Swpsegs(6,4),INTEGER Nseg,Ns,Tns,Log
flg,Logflags(6),COMPLEX Eb(20),Ib(20),Imb(20),Yb(20),Anet(2,2)
6340                COM /Lj/ Lf$[1],Cr$[1],Ff$[3],Esc$[1],Portrait$[6],Landscaqpe$
[6],Font$(4)[80],INTEGER Psc,Page,Npages,Fontnum
6350                INTEGER I,K,S,Md,Im1
6360                REAL Zm,Za,Rm,Ra,Np
6370                COMPLEX T
6371  ! Addition by Mitch Bolling to store data for plotting by PLOTTER
6372  ! program  -   Dec 1988.
6373  INTEGER Nbytes,Numrec
6374  REAL Npts
6380 Fmt1:          IMAGE "  #       FREQ(Hz)  EOUT/EIN(dB) EOUT/EIN(DEG)  ZINMAG(K
OHM)   ZINANG(DEG)"
6390 Fmt2:          IMAGE DDD,5(2X,DDDDDDDD.DDD)
6400 Fmt3:          IMAGE "PRINTING PAGE ",K," OF ",K
6401  !
6403  !   *** plot patch ***
6404 Askplot:       INPUT "Do you wish to create a PLOTTER file? (Y/N) ",Plot$
6405                Pflag=0
```

```
6406          IF (Plot$="Y" OR Plot$="y") THEN
6407             Pflag=1
6408          ELSE
6409             IF Plot$<>"N" AND Plot$<>"n" THEN Askplot
6410          END IF
6411  !   ******************
6412  !
6414          IF Psc=9 THEN
6420             Fontnum=3
6430          ELSE
6440             Fontnum=0
6450          END IF
6460          CALL Preprint
6470          Page=1
6480          Np=Tns/(10+35*(Psc=2)+55*(Psc=9))
6490          IF Np<1 THEN Np=1
6500          Npages=INT(Np)
6510          IF Np MOD Npages<>0 THEN Npages=Npages+1
6520          K=1
6521  ! *** plot patch ***
6522  !
6523          IF Pflag THEN
6524             Npts=0
6526             FOR I=1 TO Nseg
6527                CALL Seg2f(I)
6528                Npts=Npts+Ns
6529             NEXT I
6531             Nbytes=(INT((Npts*2*8)/256)+1)*256
6533             ASSIGN @Buffer TO BUFFER [Nbytes];FORMAT OFF
6534             Num_rec=INT(((2*Npts+1)*8)/820)
6535             IF (((2*Npts+1)*8) MOD 8200)<>0 THEN Num_rec=Num_rec+1
6536             INPUT "Enter the file name for the Plot: ",Pfile$
6537             CREATE BDAT Pfile$,Num_rec,8200
6538             ASSIGN @Path_1 TO Pfile$
6539             OUTPUT @Path_1;Npts
6540             TRANSFER @Buffer TO @Path_1;COUNT (Npts*2*8),CONT
6541          END IF
6542 !   ****************
6543          FOR S=1 TO Nseg
6544             CALL Seg2f(S)
6550             F=F1
6560             FOR I=1 TO Ns
6570                Im1=I-1
6580                Md=K MOD (10+40*(Psc=2)+55*(Psc=9))
6590                IF Md=1 THEN
6600                   CALL Prth
6610                   IF Psc<>CRT THEN OUTPUT CRT USING Fmt3;Page,Npages
6620                   PRINT USING Fmt1
6630                   Page=Page+1
6640                END IF
6650                CALL Compeiy
6660                T=Eb(0)/Ib(0)
6670                Rec2pol(REAL(T),IMAG(T),Zm,Za)
6680                T=Eb(Nb)/Eb(0)
```

```
6690                     Rec2pol(REAL(T),IMAG(T),Rm,Ra)
6700                     PRINT USING Fmt2;K,F,FNDb(Rm),Ra,1.E-3*Zm,Za
6701  !
6703  !            *** plotter patch ***
6704                     IF Pflag THEN
6705                        OUTPUT @Buffer;F,FNDb(Rm)
6707                     END IF
6709  !            *********************
6710  !
6711                     IF Logflg THEN
6720                        F=F*Fs
6730                     ELSE
6740                        F=F+Fs
6750                     END IF
6760                     IF K MOD 5=0 THEN
6770                        PRINT
6780                        WAIT .5
6790                     END IF
6800                     IF Md=0 THEN
6810                        IF Psc=CRT THEN
6820                           CALL Continue
6830                        ELSE
6840                           OUTPUT Psc;Ff$;
6850                           WAIT 1
6860                        END IF
6870                     END IF
6880                     K=K+1
6890                  NEXT I
6900               NEXT S
6901  !
6903  !    *** plotter patch ***
6904               CONTROL @Buffer,9;0
6905               WAIT FOR EOT @Path_1
6906               ASSIGN @Path_1 TO *
6907               ASSIGN @Buffer TO *
6908  !    *********************
6909  !
6910               CALL Postprint
6920            SUBEND ! Prtrat
6930            !
6940            SUB Prtanet
6950               COM /N/ @Path1,Netfile$[20],Cmnt$(2)[80],Br$(20)[6],INTEGER Nb
,REAL R(20),L(20),C(20),Clk$[80]
6960               COM /C/ REAL F,W,F1,F2,Fs,Swpsegs(6,4),INTEGER Nseg,Ns,Tns,Log
flg,Logflags(6),COMPLEX Eb(20),Ib(20),Imb(20),Yb(20),Anet(2,2)
6970               COM /Lj/ Lf$[1],Cr$[1],Ff$[3],Esc$[1],Portrait$[6],Landscaqpe$
[6],Font$(4)[80],INTEGER Psc,Page,Npages,Fontnum
6980               DIM S$[80]
6990               INTEGER I,Indx,S,Md,Im1,J,K
7000               REAL Xm,Xa,Xr,Xi,Np
7010               COMPLEX T
7020 Fmt1:         IMAGE "F(Hz) = ",2X,DDDDDDD.DD,"          MAG       ANG(DEG)
        REAL          IMAG"
7030 Fmt2:         IMAGE 14X,"A[",D,",",D,"]",4(2X,SD.DDDDDESZZ)
```

```
7040 Fmt3:        IMAGE "PRINTING PAGE ",K," OF ",K
7050              IF Psc=9 THEN
7060                 Fontnum=3
7070              ELSE
7080                 Fontnum=0
7090              END IF
7100              CALL Preprint
7110              Page=1
7120              Np=Tns/(3+8*(Psc=2)+12*(Psc=9))
7130              Npages=INT(Np)
7140              IF Np MOD Npages<>0 THEN Npages=Npages+1
7150              Indx=1
7160              FOR S=1 TO Nseg
7170                 Seg2f(S)
7180                 F=F1
7190                 FOR I=1 TO Ns
7200                    Md=Indx MOD (3+8*(Psc=2)+12*(Psc=9))
7210                    IF Md=1 THEN
7220                       CALL Prth
7230                       IF Psc<>CRT THEN OUTPUT CRT USING Fmt3;Page,Npages
7240                       Page=Page+1
7250                    END IF
7260                    CALL Cascade
7270                    PRINT USING Fmt1;F
7280                    FOR J=1 TO 2
7290                       FOR K=1 TO 2
7300                          Xr=REAL(Anet(J,K))
7310                          Xi=IMAG(Anet(J,K))
7320                          Rec2pol(Xr,Xi,Xm,Xa)
7330                          PRINT USING Fmt2;J,K,Xm,Xa,Xr,Xi
7340                       NEXT K
7350                    NEXT J
7360                    IF Logflg THEN
7370                       F=F*Fs
7380                    ELSE
7390                       F=F+Fs
7400                    END IF
7410                    IF Md=0 THEN
7420                       IF Psc=CRT THEN
7430                          CALL Continue
7440                          PRINT
7450                       ELSE
7460                          OUTPUT Psc;Ff$;
7470                       END IF
7480                    END IF
7490                    Indx=Indx+1
7500                 NEXT I
7510              NEXT S
7520              CALL Postprint
7530           SUBEND ! Prtanet
7540           !
7550           SUB Prtlev
7560              COM /N/ @Path1,Netfile$[20],Cmnt$(2)[80],Br$(20)[6],INTEGER Nb
,REAL R(20),L(20),C(20),Clk$[80]
```

```
7570                    COM /C/ REAL F,W,F1,F2,Fs,Swpsegs(6,4),INTEGER Nseg,Ns,Tns,Log
flg,Logflags(6),COMPLEX Eb(20),Ib(20),Imb(20),Yb(20),Anet(2,2)
7580                    COM /Lj/ Lf$[1],Cr$[1],Ff$[3],Esc$[1],Portrait$[6],Landscaqpe$
[6],Font$(4)[80],INTEGER Psc,Page,Npages,Fontnum
7590                    INTEGER Indx,I,J,S,Md,Im1,Lpi,Ipp
7600                    REAL Em,Ea,Im,Ia,Zm,Za,Np
7610                    COMPLEX T
7620 Fmt1:              IMAGE "FREQ (Hz) = ",K
7630 Fmt2:              IMAGE " #  BRANCH     EMAG(V)  EANG(DEG)    IMAG(mA)  IANG(DEG
)  ZMAG(KOHM)  ZANG(DEG)"
7640 Fmt3:              IMAGE DD,2X,AAAAAA,2X,DDDDDD.DDD,2X,DDDDD.DDD,2X,DDDDDD.DDD,2X
,DDDDD.DDD,2X,DDDDDD.DDD,2X,DDDDD.DDD
7650 Fmt4:              IMAGE DD,2X,AAAAAA,2X,DDDDDD.DDD,2X,DDDDD.DDD,2X,DDDDDD.DDD,2X
,DDDDD.DDD
7660 Fmt5:              IMAGE "PRINTING PAGE ",K," OF ",K
7670                    IF Psc=9 THEN
7680                       Fontnum=3
7690                    ELSE
7700                       Fontnum=0
7710                    END IF
7720                    CALL Preprint
7730                    Page=1
7740                    Lpi=Nb+4
7750                    Ipp=INT((14+42*(Psc=2)+64*(Psc=9))/Lpi)
7760                    Np=Tns/Ipp
7770                    Npages=INT(Np)
7780                    IF Np MOD Npages<>0 THEN Npages=Npages+1
7790                    Indx=1
7800                    FOR S=1 TO Nseg
7810                       CALL Seg2f(S)
7820                       F=F1
7830                       FOR I=1 TO Ns
7840                          Md=(Indx MOD Ipp)+(Ipp=1)
7850                          IF Md=1 THEN
7860                             CALL Prth
7870                             IF Psc<>CRT THEN OUTPUT CRT USING Fmt5;Page,Npages
7880                             Page=Page+1
7890                          END IF
7900                          CALL Compeiy
7910                          PRINT USING Fmt1;F
7920                          PRINT USING Fmt2
7930                          FOR J=0 TO Nb
7940                             Rec2pol(REAL(Eb(J)),IMAG(Eb(J)),Em,Ea)
7950                             Rec2pol(REAL(Ib(J)),IMAG(Ib(J)),Im,Ia)
7960                             IF Ib(J)<>CMPLX(0,0) THEN
7970                                T=Eb(J)/Ib(J)
7980                                Rec2pol(REAL(T),IMAG(T),Zm,Za)
7990                                PRINT USING Fmt3;J,Br$(J),Em,Ea,1.E+3*Im,Ia,1.E-3*
Zm,Za
8000                             ELSE
8010                                PRINT USING Fmt4;J,Br$(J),Em,Ea,1.E+3*Im,Ia
8020                             END IF
8030                          NEXT J
8040                          IF Logflg THEN
```

```
8050                           F=F*Fs
8060                        ELSE
8070                           F=F+Fs
8080                        END IF
8090                        IF Ipp=1 THEN Md=0
8100                        IF Md=0 THEN
8110                           IF Psc=CRT THEN
8120                              CALL Continue
8130                           ELSE
8140                              OUTPUT Psc;Ff$;
8150                           END IF
8160                        ELSE
8170                           PRINT
8180                        END IF
8190                        Indx=Indx+1
8200                     NEXT I
8210                  NEXT S
8220                  CALL Postprint
8230               SUBEND ! Prtlev
8240               !
8250               SUB Entswpsegs
8260                  COM /C/ REAL F,W,F1,F2,Fs,Swpsegs(6,4),INTEGER Nseg,Ns,Tns,Log
flg,Logflags(6),COMPLEX Eb(20),Ib(20),Imb(20),Yb(20),Anet(2,2)
8270                  INTEGER S
8280                  DIM S$[80]
8290 Fmt1:            IMAGE "SEGMENT ",D,X,#
8300                  Tns=0
8310                  CALL Entint("NUMBER OF SWEEP SEGMENTS",Nseg)
8320                  FOR S=1 TO Nseg
8330                     CALL Seg2f(S)
8340                     OUTPUT S$ USING Fmt1;S
8350                     CALL Entswp(S$)
8360                     Tns=Tns+Ns
8370                     CALL F2seg(S)
8380                  NEXT S
8390               SUBEND ! Entswpsegs
8400               !
```